PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

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A NEAT ROADSIDE ON A FEDERAL-AID PROJECT IN MASSACHUSETTS

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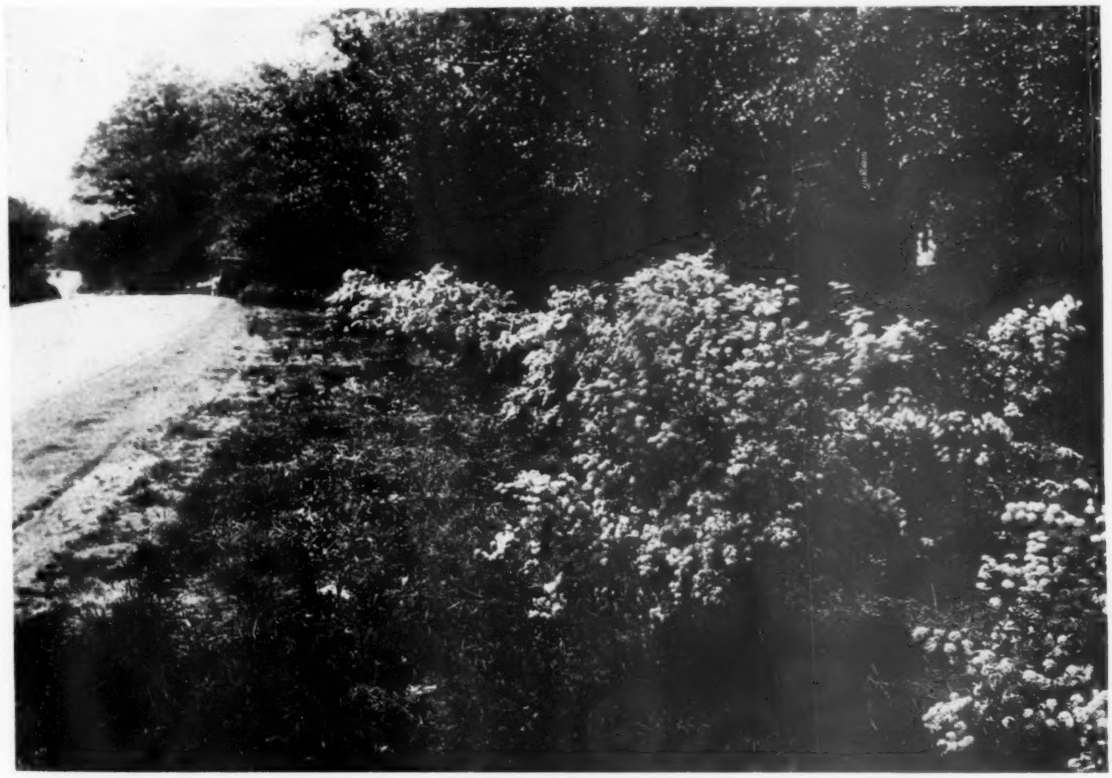
ROADSIDE PLAN AND PROGRESS IN MASSACHUSETTS

By JAMES H. TAYLOR, Highway Landscape Supervisor, Massachusetts Department of Public Works

THE considerable interest shown in the work which Massachusetts is doing in beautifying its roadsides indicates that a description of the methods and objectives of this work may be of assistance to others who are just entering this field.

The Massachusetts Highway Commission has from its beginning appreciated the value of highway beautification. Prof. N. S. Shaler the first chairman of the commission said, in 1898, "It is evident that our culture is near the station when we may hope for some effort to develop the landscape sense by a systematic training in the arts which may enable us to appreciate scenery." It is doubtful if this interest resulted in actual plantings at that time but in 1912 a man was appointed with the duty of planting trees along the State highways and for several years many thousands of shade trees were planted.

The scope of this work was enlarged in 1921 by the creation of an office to be filled by one with special training in landscape planting to "beautify the State highway roadsides" and it has progressed since then with certain definite aims and accomplishments.



AS WE APPROACH THE TOWN

ORGANIZATION OF WORK OUTLINED

Roadside planting is considered as a phase of maintenance and is under the supervision of the engineer in charge of State highway maintenance. It is financially supported by an allotment for the specific purpose. This activity is entirely separate from a related maintenance activity of tree work, brush cutting, grass mowing, etc. There is cooperation, however, in carrying on the two activities so as to secure the best improvement of roadsides.

The State highway system of Massachusetts includes 1,600 miles of road and is divided into seven highway districts. Our aim is finally to make each district sufficient unto itself in the matter of tree and roadside care by the perfecting of district units for this distinct purpose. Naturally this plan is slow in developing.

At present, work is carried on from a base in the centrally located town of Palmer. Here we have 12 acres of nursery, seed beds, propagation frames, greenhouse, storage cellar, forge, sheds for housing and storing machinery, explosives, and necessary materials. From this base we are in constant readiness to give efficient and state-wide service, adequate to any roadside need, whether it be planting, care, repair, or removal.

A State nursery is a necessity in roadside development on any worth-while scale. It is needed as a propagating area, for space to take advantage of planting stock bargains, for planting collected stock and growing until fit for the roadside, for studying the characteristics of plants and their adaptability to the roadsides; in fact, the nursery is the laboratory and experimental station of roadside development.

The planting of "small stuff" on roadsides is a waste of money. The stock used in Massachusetts work has

been given careful attention, the top and root pruned, transplanted, grown to a good size and sufficient ability to meet the rugged demands of the roadside. It has been found that trees 10 to 12 feet high are the most desirable size for planting; while shrubs should be 3 to 4 feet high and vines should be 3 to 4 years old. Freshly dug stock of this type, properly located and planted, has a fighting chance.

Three tree crews are kept in operation throughout the year, each crew consisting of a tree agent and three men. Two of the crews are equipped with a camp wagon (small house on wheels) fitted to house comfortably four men. These portable bases are very satisfactory and economical.

Plantings, in the main, are confined to new right of ways since their width of 60 feet or more allows greater opportunity for landscape development. Such locations assure a reasonably undisturbed future, but it is a rule in every case to plant as near the property line as possible, for wider road surfaces are sure to come.

The planting procedure is as follows: A blue print showing the right-of-way lines and road location is sent to the Palmer station. The designer makes a study of the road and indicates the proposed planting on the blue print. The locations of plants or trees are then staked and the pits dynamited, dug, and where necessary refilled with the best loam obtainable. Tree pits are 3 feet in diameter and 3 feet deep and shrub pits are 2 feet in diameter and 2 feet deep. The planting order is filled by the nursery, packed on trucks and trailers, and set out in the field.

A space 3 feet in diameter around each plant is grubbed and kept free from weeds, and water is supplied if needed. After the planting is well started it is given a final inspection and turned over to the district maintenance forces for care.

Using the work done by our Palmer organization as a criterion for the district maintenance forces we are trying to produce a highway hybrid; a cross between a surface expert, a tree surgeon, and a landscape designer. We are educating a small army of men whose primary interest is in the road surface, whose natural attention is to lines and grades, pot holes and breaks, tar barrels and side drains, and interesting them in vines, shrubs, trees, and the æsthetics of the roadside. Responses differ as men differ; the result is not uniform but the general tone is one of splendid cooperation.

Depressions in the road surface are known to the maintenance man as "pot holes." The roadside developer detects what may be called "pot holes" in the highway landscape and corrects the situation, sometimes by filling in; sometimes by removing detracting or barrier material.

Advising as to this work, Prof. Charles S. Sargent, the noted dendrologist, designer, and director, of the Arnold Arboretum said, "Avoid the artificial; keep the roadsides as natural as possible." This is wisdom for everybody—everywhere.

We have our particular portion of earth. It is not California or Indiana, nor yet New Hampshire. It is Massachusetts. Possibly others may have better methods of working; we shall use them. The pattern treatment of a slope or a traffic island by others may be helpful to us. We may imitate in many operative details, but as for the main scheme, we are working on a canvas where copying is out of the question; the developing of the individuality of our own home State.

When July is hot upon the earth, to roll from the sun-smitten surface to the refreshment of a tree-arched way with its cool pavement and mosaic of light and shade, is a welcome change that everyone appreciates. However, this treatment reproduced for mile after mile would finally affect us as a depressing monotony. In many cases we are compelled to adopt a formality of arrangement, but barring that, the planting of long stretches of evenly spaced and straight-lined trees and shrubs is ignorance, not art. However pleasing such treatment may be to some, to others it suggests artificiality, unnaturalness, stiffness, and the hand of man.

In city and village locations we are definitely limited and the planting is of necessity formal. The centers of homes and business furnish the extreme problems of the tree planter. At best the tree will have a fight for life. If the walk is concrete or brick a 3-foot opening for the tree is not too large. This opening must be kept cultivated and water and fertilizer introduced as needed.

Long before the period of general road improvement there was a scattered interest in shade tree planting, to which certain rows of ancient trees bear splendid testimony. These historical plantings, if left to themselves, will finally vanish. It is our duty to perpetuate them, and as they die, to replace with like varieties.

NATIVE PLANTING MATERIAL PLENTIFUL

The tendency of the planter is to assume that, in reason, almost anything will grow almost anywhere. An example of thoughtless planting was seen several years ago on the Bourne-Plymouth road. A coarse gravel slope that lay from 10 to 6 o'clock each day in the summer sun, was planted by some well-intentioned but misguided enthusiast with numerous clumps of that delightful shade-loving plant—the mayflower. The brown, dead leaves told the story.

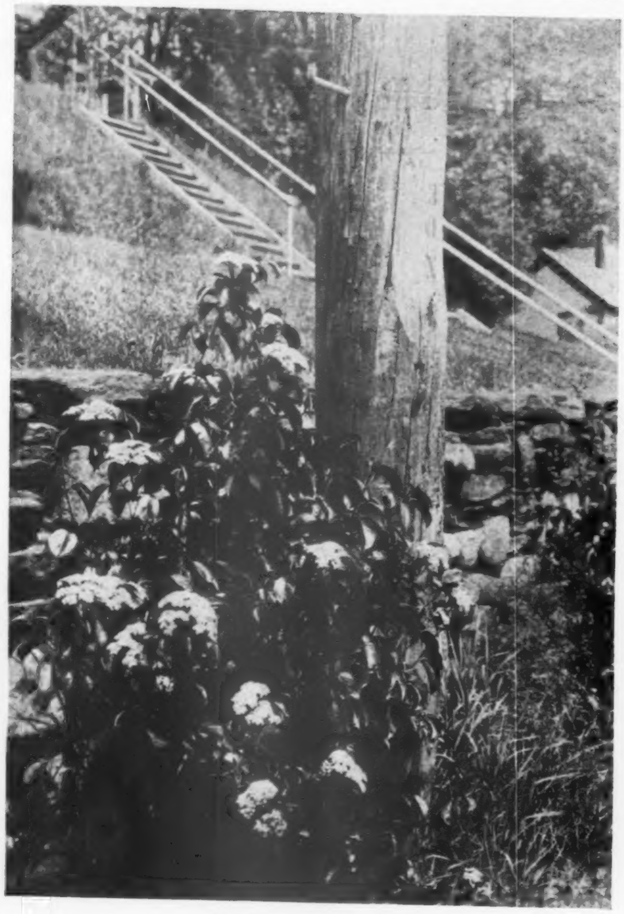
There is a tendency to introduce foreign plants on the roadside. This may be done to a moderate extent as the road approaches or extends through a town or village where the local planting suggests it and into which it blends. Beautiful as they may be in themselves a hydrangea or forsythia in our ordinary natural roadside would be a triumph of absurdity and discord. A Colorado blue spruce would be distinctly out of place. It is not Massachusetts, but rather, artificial. Importations are attractive but a State's personality is more so.

Our State is lavishly supplied with native planting material. From the time when the shad-bush prints its misty pattern upon the gauze draperies of spring, to the witch-hazel's farewell gleam of gold within the leafless woods we have a changing picture of flora and sylva; of graceful vines and leafy forms that is unsurpassed, even by the splendor of the tropics; and, adjusting ourselves to local preferences, here is our field of choice.

All of our roadside pictures exist in three parts—foreground, middle-distance, and background. If our compositions are to be successful this fact must be appreciated in both our selective trimming and our planting. The planter must know the dimensional limits and contrastual possibilities in shape, texture, and color; bark, leaf, and flower; spring aspect, summer maturity, autumn glory, and winter value; in other words, he must have a complete knowledge of growing things.

The roadside is neither a lawn nor a back-yard garden; it is a problem apart. Where one shrub would

In Competition with the Enemy



A Helpful Touch

Sweet Fern Development

produce a splendid effect in your garden, it will take a hundred to approach an effect on the stretch of the roadside. We are working on a big program and we must mass our planting correspondingly. But, never forget the immense value of individual specimens. This seems in contradiction to the above, but the meaning is this—do you remember that magnificent 6-stemmed paper birch, that perfect elm by the old homestead, the triumphant white oak on the hill? You forget everything else for the moment and the memory is still a delight. Rightly planned, the little trees you plant today will impress in like manner an unborn generation; the willow by the water-brook, the fadeless cedar, the oak of scarlet. A finished surface never improves—a planting does. It is an immediate improvement and the improvement keeps on improving.

a 5 and a 7 foot blade for use on large trees is a good investment. Where the log is the right kind and size, it is milled into tree stakes, chestnut being the most desirable.

Trees should have constant and thorough inspection; for it often happens, that a tree presenting a fair face to the road, is merely a shell from the other side and is ready to fall with the first strong wind.

Hardly a day passes without some good tree being wounded by machines either carelessly guided or out of control. The resultant scars are unsightly and dangerous to the tree. They become the open door to disease, and should, as soon as dry, be neatly trimmed and properly sealed with a durable tree paint and recoated as necessary. It is claimed by some that tar or asphalt paint is not good for the tree and retards

Tree Insurance

the growth of the cambium. Our experience does not lead to this belief.

Where the tree is a large one the effect of the impact is a wound only, but small or moderate size trees are pushed out of line and should be brought back into the vertical and wired or staked.

Decay in normal trees is largely traceable to either the breaking of large limbs and failure to treat the fracture properly or the neglect of trunk or limb wounds. Decayed areas should have careful attention. All decay should be removed, and if the area is in a rigid portion of the tree and is not too large it may be filled with a mortar of cement and clean, coarse sand, mixed in the proportion one to three, and as dry as practicable. The mortar should be tamped thoroughly to fill the entire space, and smoothed up to the inner edge of the cambium. A cross section through a tree shows that it has four divisions, heart wood, sap wood, cambium, and bark. The cambium is the life center of the tree;

The various types of embankment guards whether wood, wire, natural or cast stone, while of admirable purpose are not beautiful. They may be made less objectionable by background plantings of suitable character. For example the harsh outlines of guard stones may be beautifully softened by a setting of viburnum opulus. Its rugged foliage, white flower cluster and crimson fruit fuse these stern profiles into a most delightful harmony.

TREE SURGERY AN IMPORTANT PART OF WORK

To say that a road picture is beautiful, is merely the unconscious recognition of a certain harmony of arrangement, attaining, or approaching, a unity of expression. Dead trees and limbs deface the picture; they are a menace to traffic and should be removed at once. Our practice is to cut trees six inches below the surface of the ground. It costs a bit more, but the manifest improvement justifies it. A power saw with

We Once Mowed These

Private Work on State Slopes

the living tissue from which all growth proceeds; this cambium is the natural protection of the tree. As soon as the tree is wounded the cambium starts its healing work, by beginning to spread itself over the wounded surface. Examine any cut or wound and you will see just what it does. Many times, where a limb has been properly cut and protected, the cambium has completely covered the exposed area, in some cases, even up to 6 or 8 inches.

In most cement-mortar fillings that have been properly made, the cambium of a healthy tree will, in one year cover the edge crack due to the drying out of the mortar. The larger the filling the wider the shrinkage crack, and where the crack is left open, water enters and causes decay. This can be prevented by filling to within an inch of the surface with mortar, allowing it to set, and finishing with a seal coat of asphalt and sand, mixed warm, just so that it will not run, and tamped firmly into place. Where limbs are subject to bends and twists, cement mortar should not be used; but a mixture of asphalt and sand or sawdust may be used.

Covered decay is a dangerous thing. Fires have been built in cavities and blow torches used to get at otherwise inaccessible spots. When a cavity can be drained it may be disinfected, painted, and observed from time to time to see if further attention is needed.

High winds and loadings of snow and ice, separately or in combination, do the greatest damage to trees and some are not able to stand them. Compound fractures are, of course, hopeless, but simple splits can be successfully treated by the intelligent use of metal rods or cable. In one case an elm, split in two with one half nearly to the ground, has been made fit for half a century of roadside blessing, by drawing the parts together, installing cable, and calking the crack. To-day it looks as perfect a specimen as before the separation.

The points at which metal ties are introduced is vital. Much of the metal reinforcing of split trees looks like the work of children, as far as the proper planning for the strain is concerned. These jobs call for a man who understands the mechanics involved. No definite rule can be given but an approximate formula is that support should be applied at a distance from the beginning of the split of ten times the diameter of the limbs split.

Split trees are repaired with five-eighths or three-fourths inch galvanized wire cable secured to three-fourths or seven-eighths inch eyebolts using galvanized eyes and galvanized cable clips for fastening. An experienced tree man will anticipate weak points in the tree structure, and apply the necessary support before a break occurs.

REGULAR MAINTENANCE GIVEN ALL PLANTINGS

All trees planted since 1921 have been given annual attention. The ground is kept open about their base for food and air, and where necessary the roots are fertilized. The trees are staked as required. Leaning specimens are brought into the vertical, and, where the tops are not developing properly, a new "leader" is established. The leader is the highest point of a tree, in general line with the main stem and trees are by nature designed to "follow the leader." Sometimes there are two leaders, and, one must be removed for proper development. Again, there may be no leader, but a jumble of growth which dwarfs the top, and a stick or bamboo must be lashed to the main stem, and the most promising branch tied to the splint; the branch thus forced into action will gradually accomplish the desired purpose.

Trees carefully planted and cared for grow, but with a tendency to become top heavy with foliage. This requires the intelligent removal of enough of the tops to give them a chance to resist wind pressure; not by mere shortening of the terminals, for then we get four or five sprouts instead of one, but by the removal of entire branches, cutting them off at the outer edge of the collar of the limb. The collar is the enlargement of the limb at its union with the main member. Proper pruning leaves a symmetrical tree and the tree must be viewed from all sides and at some distance, during the process, to get the total effect.

Many people have the idea that a tree should be trimmed to resemble an inverted broom or lollypop; this is incorrect. Most of our northern trees are of a tapering nature, the elm being a conspicuous exception. The pruning of a young tree should suggest the ultimate outline, and leave it in somewhat the shape of an elongated egg, but slightly larger at the base. Limbs can be removed for about 2 feet above the ground. Those above this height should be cut back, but not removed. They can be allowed to remain for years, as they divert the flow of sap and thereby increase the trunk diameter, making the structure self-reliant.

The competent tree man never makes a cut without the future tree in mind, and one can make or break a tree's future during its early training. Branches that will ultimately rub and break can be detected and abnormal growth corrected.

NATURAL GROWTH SHOULD BE PRESERVED

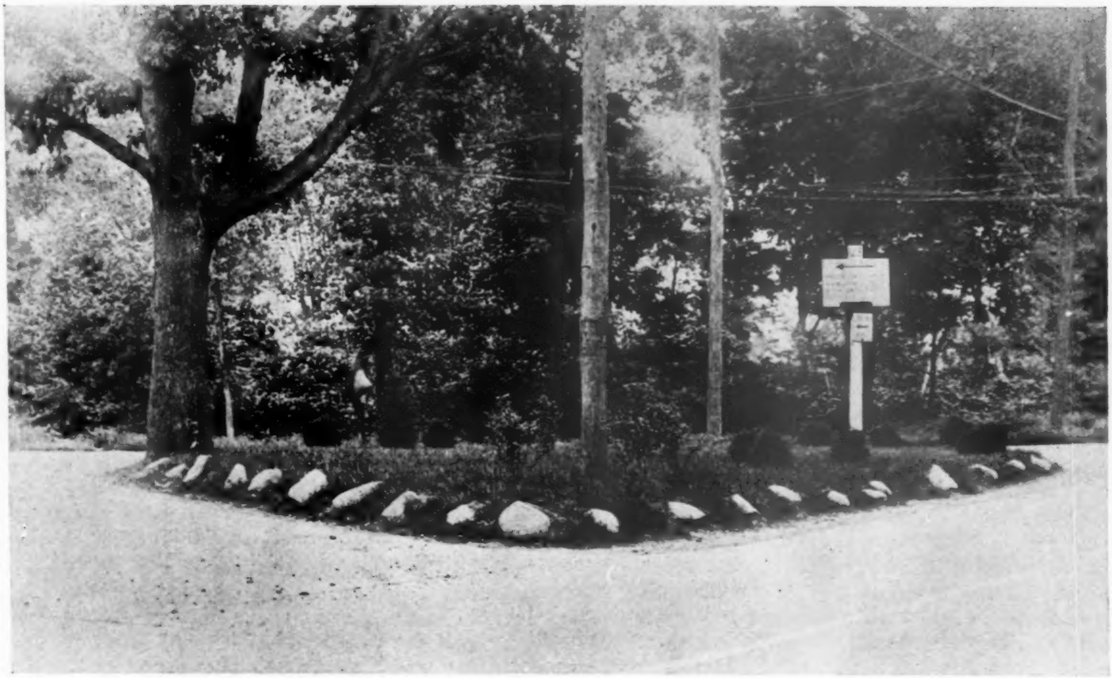
The preservation of naturally planted growth is the most important part of roadside development. Failure to appreciate this wealth of resource is deplorably general. What is known as "brushing the road" ordinarily means mowing down every green growing thing clean to the wall or line.

Hardwood and evergreen trees, desirable shrubs, vines, and plants, at a reasonable distance from the traveled way should be spared and developed, and anyone accomplishing this is contributing in a splendid way to the future beauty of roadsides.

Nature is the master planter; man's work is, at best, but a weak imitation. Take, for instance, that glory of New England, the common elderberry, which nature gives us in such lavish profusion. It is quite difficult to transplant and establish it, even in the same general location; and next to impossible with its sister the mountain elder (red berry). We can say the same thing of the unique tupelo, one of the most brilliant lights in our autumn picture. One often finds tupelo seedlings in the roadside south of the Blue Hills and we of the roadside should know enough to observe and to spare it. Sassafras, tulip, canoe birch, cedar, and a lot of others, in the hard-to-transplant group, have all settled in our roadsides and we must keep them there.

A sugar maple may have been self-sown in the border and grown to a sapling. The surrounding growth should be cut away, and the young tree trimmed in the manner described for young planted trees. Desirable shrubs, sumac, benzoin, that wonderful group, the viburnums, the cornels, American plum, laurel, and all the others in our comely family should be counted as roadside treasure, and developed in groups and individually.

I can think of no more wonderful picture than a Cape Cod road in May framed in the beach plum's flowery bloom, but these roads have, in many places,



Traffic Island Treatment

Two Birds with One Stone

been shorn of this beautiful shrub. Someone, who did not quite understand, had been told to mow the roadsides.

Let the woodbine, grape, wild clematis, and even the poison ivy ramble over the wall; the latter is fond of mature elm trunks, to which it does no harm and in the autumn it is a roadside marvel of crimson and gold. But when an ambitious grape-vine attempts to throttle a member of our beautiful shrub family—spare it not.

In the same spirit of appreciation—let us give our roadside ferns place; could anything be more beautiful than clumps of their graceful fronds? A few miles of road comes to mind whose borders were two years ago a very jungle; to-day by the mere sparing of sweet fern, it surpasses any man-planted effects that I can imagine. In this same district and over a distance of perhaps 275 miles, I do not think that one roadside fern was cut down. Such is the way in which one really interested man projects himself into the district force which he directs.

Cut away the underbrush and lower branches of the gray birch and let their silver trunks shine out. If blue lupin ventures out to watch the traffic, don't frighten it away with a scythe—and give the same treatment to groups of lilies that have slipped from garden bonds to the freedom of the roadside; or why should pine weed or the trailing blackberry be sheared to the roots? They make an attractive and inoffensive carpet.

CUTTING FOR ROAD CLEARANCE AND SIGHT DISTANCE REQUIRES CAREFUL THOUGHT

When highway traffic was largely horse drawn not much thought was given to bends in the road. To-day we are making the roads safer by relocation and by clearing the blind corners. This requires the removal of much otherwise valuable material. Cuttings are made as graceful as possible and none is made that gives a straight line or a regular curve.

An overhead clearance equal to the legal height of load should be maintained over the road surface and shoulders. The popular method seems to be to remove only the interfering branches over the hardened surface. The tree should not be left lopsided, but balanced by thoughtful trimming on both sides.

A large proportion of our highways have lines of telephone or telegraph wires along them and their requirements as to tree clearance are almost continually in conflict with proper shaping and placing of trees. The public wants its roadsides made beautiful, but it must also have its lines of communication and neither of these things can be entirely subordinated to the other. In the past there has been much thoughtless and some designed mutilation of trees by wire-maintenance gangs, but the public-service companies now wish to avoid offenses of this kind. The State itself is in advance of most other States as the law now requires that all trimming for wire clearance be done under the supervision of an inspector from the State's roadside planting organization. The expense of this inspection is paid by the public-service company.

Careful cutting for wire clearance under proper inspection is of great value, but there is a better solution of the problem. A number of wires suspended from cross arms on 50-foot poles is, at best, an aesthetic offense. An equal number of wires, inclosed to make a 2 or 3 inch cable, supported on 25-foot poles and half hidden among the trees, makes a splendid improvement. This has been done in some instances in Massachusetts.

LANDSCAPE CUTTING OPENS UP WONDERFUL VISTAS

Trees, shrubs, and vines are wonderful, but when their beauty hides the more beautiful, the tumbling brook, the foaming river, green fields, rolling hills, and blue mountains, then these screens must be offered upon the altar of beauty. To this end we have sacrificed many trees which raised green curtains on some beautiful scene. Massachusetts teems with such opportunities.

In Agawam half a day's work with three or four men unveiled a splendid view of the Connecticut. When a photographer was sent to photograph the improvement he found an artist engaged in making a representation in oil. A few hours with an ax on a curve in West Warren brought out a gem of distant hills and winding stream for the delight of the traveler.

In Palmer, on the river road, the tumbling Quaboag was heard behind an intervening jungle. There was more work here, but the result justified it; a splendid composition of water and trees. A delightful river fringe was brought in view where scores rest at noon and are refreshed and refitted for the journey.

There are spots along this hitherto hidden river in Palmer that a few years ago were snarls of vagrant undergrowth; to-day they are pictures in the roadside gallery which suggest in their soft outlines the composition of a great artist. It takes intensive and continuous study, this painting pictures with an ax; but it pays substantial dividends in both conscious and subconscious pleasure to the highway user.

TRAFFIC SIDINGS, SPRINGS, AND BENCHES PROVIDED FOR THE CONVENIENCE OF PUBLIC

There are many little touches which may be given a highway to add to the public's enjoyment. Spaces along the highway have been cleared and graded at small expense to serve as traffic sidings, where a tire may be changed, a lunch enjoyed, or a nap taken. A fine spring drooling itself away in gutter mud, has, by a few hours' work, been changed from a nuisance to a roadside blessing.

Durable chestnut benches with concrete ends anchored in the earth have been placed in appropriate places.

CONSTRUCTION SCARS HIDDEN WITH A SUITABLE COVER

New construction generally leaves unsightly faces in cuts and fills. Where these slopes occur in residential sections it is a rule to either seed or sod them, and more and more of this kind of work is being done in open country. Where seed is to be planted the slope must be coated with at least 2 inches of loam. In one case a cut slope, 1,000 by 20 feet, was covered with sod from a pasture at the top of the slope at very low cost. Rain followed, and the result was excellent.

Loam is a necessity in roadside planting and is often difficult to procure. The specification should provide for the removal of all sod and loam and storage in neat piles for future planting use. If the soil is of suitable character grape vines, woodbine, wild clematis, and Hall's honeysuckle may be used. The latter makes the quickest ground cover. A slope of chipped stone and gravel had been bare for years. A scant inch of loam was applied and sown with red clover—rain came at just the right time. It was beautifully green in two weeks and was mowed 41 days after sowing the seed. Common daisy seed, sown on seemingly hopeless slopes, will, in time, give surprising results.

Sweet fern is admirable, but difficult to transplant; one is well repaid, however, for the trouble where the planting is successful.

The bearberry, or, as commonly known "hog cranberry" is a distinctly beautiful ground cover. A ride to Provincetown by rail shows how splendidly it has clothed the harsh railroad cuts and fills. Nothing so fits into a Cape Cod road slope or border as this glistening vine of changeable green, with its pink bells and crimson fruit. It is distinctly a sand plant and will not thrive except in apparently supersterile soil. With this characteristic in mind it should be used wherever possible. Unfortunately it is as hard to adapt to a new location as it is to kill it in its chosen places.

The uncovered material in the larger cuts is generally very poor planting ground. For broader areas of this kind transplanted pine seems to be most suitable. Jack pine grows the quickest but its habit is to make a thin and scrawny growth. Scotch pine is harder to establish but has a more desirable shape, and red and white pine are excellent. After a few years these plants hold a slope in place. If they are allowed to grow too tall they are apt to tip over. This may easily be prevented by keeping them well cut back. Jack pine needs this treatment more than the others as its roots are not quite able to keep the top from leaning. Bare slopes are unsightly and the roadside man must keep at them until they are made an asset to the picture.

TRAFFIC ISLANDS MADE INTO BEAUTY SPOTS

Triangular areas formed by intersecting highways are of frequent occurrence. Their outlines are generally ragged, cars are driven and backed over them and generally they reflect a decidedly don't-care spirit. Such spaces should be covered with loam to a foot above the surrounding surface and bordered with a curb of light colored stones.

An arborvitae (pyramidalis) may serve as a background to a possible warning sign, or a vine plant may be placed at the base of a direction post. Of course the planting must not obscure traffic—low growing plants such as Japanese yew and juniper of the spreading type—euonymus radicans, hydrangea arborescens, Tom Thumb, and globe arborviteae are suitable. If the area is large enough, a few slim cedars can be used with fine effect, also almost any kind of shrub in groups, but the latter must be kept well cut back. When the planting has been, made the remaining space should be seeded with Kentucky bluegrass and red fescue grass in the proportion 3 to 1, and rolled. And then this most important thing—don't neglect the improvement—keep the grass mowed.

ROADSIDE NEATNESS REQUIRES THAT ATTENTION BE GIVEN TO SMALL DETAILS

Every tourist passing through a State carries away with him an impression of the character of its people, and this impression is undoubtedly influenced by the neatness of its roadsides. If a warning sign becomes soiled and torn, don't let it broadcast your carelessness; replace it with a fresh one. If a traffic line is put on, make it straight and symmetrical. Mend your broken guard fence without unnecessary delay. Remove the cut brush as soon as you make it, and it is safer to burn when green. Departmental neatness influences the public mind; it is another case of "follow the leader." Community clubs have placed waste receptacles in several locations lettered, "Please use this for waste," or "Keep Cape Cod clean."

On every construction job a finished roadside should accompany a finished road surface, and both should be considered in the acceptance of the road. There is no reason why maintenance money should be spent to do what the contract called for. Practically all road contracts have a clause to the effect that the "section shall be left in a workmanlike manner" and this clause should be enforced. There should also be a clause providing against burning, breaking, and barking the roadside growth.

KEEPING AT IT

The most important thing in roadside development is the provision for a permanent program. Lacking that means a waste of public funds. I call to mind a State that started roadside development 10 years ago, and very elaborately at that. In a late census of roadside improvement activity the same State was shown to be practically inactive.

Everything finally resolves itself into maintenance. Roadside development should be begun at once; it never can be finished. I feel very deeply that what the roadside needs most is not that improvement be begun merely, but that it be continued; that a fixity of purpose be indelibly grained into the movement, to the extent of a State or national consideration that shall appreciate its importance; underwrite its future.

Roadside improvement must not rest upon the enthusiasm of one man, who, dropping out of the picture takes the vitality of the moment with him. A kind of apostolic succession must be operative in order that the rank be kept filled, so that the business of roadside beautification may maintain a program as steady and sure as that of the surface which it borders.

EFFECT OF METHOD OF FABRICATION ON STRENGTH AND UNIFORMITY OF FLEXURE SPECIMENS[1]

By L. W. TELLER, Senior Engineer of Tests, Division of Tests, United States Bureau of Public Roads

One of the problems before A. S. T. M. Committee C-9 on Concrete and Concrete Aggregates has been the standardization of the flexure test for concrete. This is a matter of particular interest to those connected with paving concrete because of the increasing use of this test as a basis for the opening of concrete pavements. The urgent need for standardization is apparent and there has already been a considerable amount of valuable discussion in the committee relative to the standardization of the equipment and procedure for testing such specimens. The matter of standardizing the procedure to be used in making the specimen is of equal importance since this procedure may influence the strength of the specimen to as great a degree as do the methods of testing.

With the idea of finding out what effect methods of fabrication have on the strength and uniformity of concrete flexure specimens the following work for the committee was undertaken at the laboratory of the Bureau of Public Roads at Arlington. The program was necessarily restricted to those factors which seemed most likely to influence the strength of the specimen and even thus limited it involved the making and testing of over 400 beams.

Briefly, the program consisted of the fabrication and testing of 12 series of 34 flexure specimens each. The 12 series included 6 methods of fabrication, using concretes made with 2 coarse aggregates quite different in physical character. The details of the program are presented below.

METHODS OF FABRICATION AND TESTING DESCRIBED

Method 1.—Rodding with a ⅝-inch diameter round steel rod. This rod was similar to those generally specified for fabricating compression specimens and is shown at the extreme left in Figure 1.

The concrete was placed in the mold in two layers and each layer was rodded twenty times.

Method 2.—This method was identical with method 1 except that each layer of concrete was rodded fifty times.

Method 3.—Spading with a special straight spade through which five large holes had been punched. This tool was made for these tests and was not according to any particular specification. The blade was about 4½ inches wide and about 6 inches long. This tool is the second from the left in Figure 1.

The concrete was placed in two layers and each layer was consolidated by cutting twenty times with vertical strokes of the spade, the blade being held at right angles to the long axis of the specimen.

Method 4.—This method was identical with method 3 except that each layer of concrete was spaded fifty times.

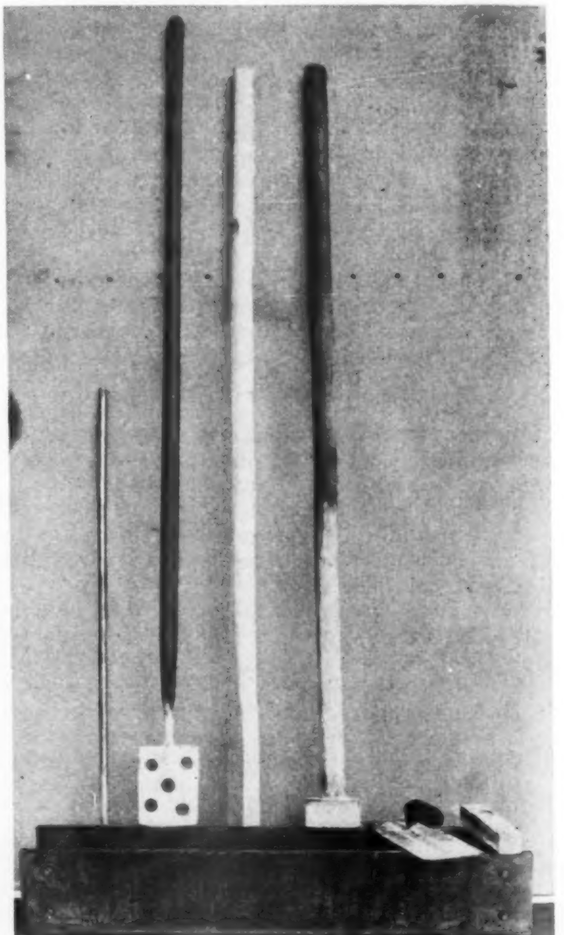


FIGURE 1.—APPARATUS USED IN FABRICATING SPECIMENS

Method 5.—Tamping with a 2 by 2 inch square wooden tamper faced on the end with a steel plate of the same dimensions.

The concrete was placed in 2 layers and tamped 45 strokes per layer. This number was arbitrarily selected as it gave one stroke per square inch of surface of the area being tamped (approximately the same as in the molding of compression specimens). This tool is shown in Figure 1, being the second from the right.

Method 6.—This method was identical with method 5 except that a tamper 4 by 4 inches in area was used and each layer was tamped ten times.

All of the specimens in this test were spaded along the sides and ends with the straight spade, the top was struck off with a wooden screed and the top surface

[1] A report made to the subcommittee on field tests of concrete of the A. S. T. M Committee C-9 on Concrete and Concrete Aggregates. A few minor changes in the orm of presentation have been made.

Table 1.—*Test results for concrete made with rounded aggregate*

Spec. No.	Method 1			Method 2			Method 3			Method 4			Method 5			Method 6		
	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average
	Pounds	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*
1	92.7	567	+6	92.0	511	−5	92.1	569	+8	91.6	563	+3	92.5	545	−1	92.4	597	+6
2	92.1	471	−12	92.1	432	−20	92.1	570	+8	91.9	513	−6	91.6	458	−16	92.3	491	−13
3	92.8	507	−5	93.0	400	−25	93.3	507	−4	92.6	598	+10	92.9	538	−2	92.1	541	−4
4	93.8	522	−2	93.9	526	−2	92.5	540	+2	92.7	571	+5	91.5	572	+4	92.1	557	−1
5	92.6	577	+8	93.1	625	+16	92.1	545	+3	92.2	603	+11	91.8	587	+7	90.9	603	+7
6	92.7	553	+3	92.7	611	+14	93.2	625	+18	91.6	553	+2	92.0	541	−1	91.7	547	−3
7	92.1	547	+2	92.5	551	+3	92.1	525	−1	91.7	520	−4	91.4	489	−11	92.6	547	−3
8	91.8	501	−6	92.4	637	+19	92.2	576	+9	92.3	551	+1	92.8	563	+3	93.1	587	+4
9	93.4	617	+15	92.7	569	+6	91.9	612	+16	91.8	541	−1	91.2	639	+17	92.4	505	−10
10	92.9	583	+9	91.8	595	+11	92.4	569	+8	91.7	555	+2	92.0	609	+11	92.6	682	+21
11	92.8	529	−1	93.0	522	−3	92.2	516	−2	92.0	561	+3	91.8	495	−10	92.1	486	−14
12	91.9	522	−2	92.3	519	−3	92.1	509	−4	92.2	589	+8	92.0	576	+5	92.5	597	+6
13	93.7	619	+16	92.6	542	+1	93.1	559	+6	92.1	523	−4	93.0	576	+5	92.5	590	+5
14	93.7	546	+2	92.5	546	+2	92.0	592	+12	93.3	499	−8	93.1	537	−2	92.1	568	+1
15	93.2	515	−4	91.7	456	−15	91.8	455	−14	91.6	529	−3	91.7	483	−12	91.7	506	−10
16	91.8	436	−9	91.9	463	−14	92.2	452	−14	92.6	520	−4	92.3	492	−10	91.7	571	+2
17	92.7	539	+1	93.4	591	+10	93.6	490	−7	92.7	559	+3	92.6	563	+3	92.7	601	+7
18	92.2	548	+2	93.2	622	+16	92.5	501	−5	92.8	559	+3	92.9	549	0	92.8	591	+5
19	92.7	444	−17	93.8	569	+6	92.4	543	+3	93.6	600	+10	92.1	583	+6	93.8	537	−4
20	92.6	493	−8	93.6	526	−2	92.8	501	−5	92.7	559	+3	93.6	573	+5	93.1	507	−10
21	92.7	643	+20	92.8	587	+9	93.1	555	+5	93.5	582	+7	93.1	585	+7	93.7	606	+8
22	92.8	660	+23	92.9	592	+10	92.8	541	+2	93.7	528	−3	93.8	605	+10	93.8	614	+9
23	93.1	578	+8	93.0	569	+6	92.0	492	−7	92.9	549	+1	92.8	475	−13	92.8	613	+9
24	93.2	475	−11	93.2	616	+15	93.3	477	−10	91.9	547	+1	92.6	500	−9	93.9	543	−3
25	93.3	515	−4	94.1	433	−19	93.0	538	+2	93.3	476	−12	92.9	547	0	92.2	491	−13
26	92.6	472	−12	93.1	490	−9	93.0	462	−12	93.0	532	−2	92.4	435	−21	92.8	589	+5
27	--------	535	0	--------	521	−3	--------	516	−2	--------	500	−8	--------	486	−11	--------	547	−3
28	--------	521	−3	--------	452	−16	--------	490	−7	--------	537	−1	--------	541	−1	--------	579	+3
29	92.2	583	+9	92.8	569	+6	92.0	551	+4	92.6	557	+2	92.3	563	+3	93.7	569	+1
30	92.7	472	−12	92.8	551	+3	92.0	482	−9	91.9	501	−8	92.6	635	+16	92.8	475	−15
31	92.7	590	+10	93.0	597	+11	93.1	576	+9	93.7	603	+11	92.3	569	+4	93.8	577	+3
32	92.7	533	0	93.3	583	+9	93.5	549	+4	91.5	606	+11	92.0	595	+9	92.8	613	+9
33	92.8	477	−11	91.7	443	−17	91.8	461	−13	93.0	454	−17	92.4	554	+1	92.5	493	−12
34	92.8	492	−8	93.5	442	−18	92.9	489	−7	92.7	456	−16	92.0	561	+2	93.2	579	+3
Average	92.7	535	8	92.8	537	10	92.8	528	7	92.5	544	6	92.4	548	7	92.6	562	7

Table 2.—*Test results for concrete made with angular aggregate*

Spec. No.	Method 1			Method 2			Method 3			Method 4			Method 5			Method 6		
	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average	Weight of specimen	Modulus of rupture	Variation from average
	Pounds	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*	*Pounds*	*Lbs. per sq. in.*	*Per cent*
1	94.5	583	+4	94.5	577	−1	94.0	496	−11	94.4	641	+15	93.6	646	+12	92.5	611	0
2	95.2	534	−4	93.5	520	−10	94.6	548	−2	94.6	541	−3	94.3	641	+11	94.1	628	+3
3	94.1	462	−17	94.3	618	+7	93.5	497	−11	93.9	653	+17	93.6	601	+4	94.0	567	−7
4	93.9	496	−11	94.0	565	−3	94.5	566	+1	94.0	575	+3	93.9	622	+7	94.7	615	+1
5	94.7	555	−1	94.1	562	−3	94.8	476	−15	94.6	494	−11	94.5	562	−3	93.9	687	+12
6	95.3	626	+12	94.7	521	−10	94.5	612	+9	94.5	492	−12	94.3	565	−2	94.1	649	+6
7	95.0	560	0	94.7	533	−8	95.4	532	−5	95.4	517	−7	94.1	556	−4	94.3	580	−5
8	94.2	518	−7	94.0	623	+7	94.6	528	−6	94.2	570	+3	94.7	492	−15	94.7	623	+2
9	94.9	618	+11	94.9	501	−14	95.3	602	+8	94.4	510	−8	94.1	591	+2	94.2	628	+3
10	95.2	432	−23	94.7	573	−1	94.6	587	+5	94.8	616	+11	94.6	605	+4	94.2	757	+24
11	94.3	547	−2	95.0	613	+6	94.2	577	+3	93.7	561	+1	94.4	577	0	94.3	657	+8
12	94.2	579	+4	93.8	685	+18	94.7	631	+13	94.1	553	−1	94.0	596	+3	94.0	623	+2
13	93.8	675	+21	94.7	570	−2	94.2	513	−8	93.9	485	−13	93.5	575	−1	93.9	553	−9
14	94.7	587	+5	94.2	[1] 345	--------	94.3	617	+10	94.0	566	+2	93.9	545	−6	93.4	531	−13
15	94.5	667	+20	93.6	650	+12	93.2	532	−5	94.1	545	−2	93.7	551	−5	93.6	602	−1
16	94.2	529	−5	93.9	643	+11	93.8	512	−9	93.9	567	+2	94.0	553	−4	93.6	658	+8
17	93.8	571	+2	94.6	638	+10	94.0	600	+7	94.3	555	0	93.7	627	+8	94.0	559	−8
18	94.4	445	−20	94.7	597	+3	93.2	595	+6	94.1	542	−3	94.4	655	+13	93.6	667	+9
19	94.4	643	+15	94.9	540	−7	94.5	628	+12	94.4	542	−3	94.7	625	+8	94.6	667	+9
20	94.9	621	+11	95.0	673	+16	94.1	628	+12	94.0	607	+9	94.4	567	−2	94.7	--------	--------
21	94.5	495	−11	94.8	532	−8	94.6	570	+2	94.8	561	+1	94.3	547	−6	93.7	532	−13
22	94.8	538	−4	94.6	562	−3	94.8	477	−15	94.3	553	−1	94.1	551	−5	94.7	591	−3
23	94.5	602	+8	94.8	533	−8	95.4	617	+10	95.4	571	+3	94.9	480	−17	94.4	536	−12
24	94.6	618	+11	95.1	538	−7	94.4	537	−4	95.6	623	+12	94.9	607	+5	93.8	631	+3
25	95.0	585	+5	94.4	546	−6	94.5	420	−25	94.7	573	+3	94.3	579	0	94.4	634	+4
26	95.4	544	−3	93.8	639	+10	94.4	[1] 371	--------	95.2	536	−4	94.3	550	−5	94.7	635	+4
27	95.2	501	−10	95.1	619	+7	94.0	663	+18	94.8	523	−6	94.6	615	+6	95.7	551	−10
28	94.3	423	−24	94.9	637	+10	94.1	583	+4	94.3	642	+15	94.3	590	+2	94.6	548	−10
29	94.3	625	+12	92.9	536	−8	94.4	599	+7	93.9	570	+3	94.7	681	+18	94.9	558	−9
30	93.8	597	+7	94.3	535	−8	94.5	527	−6	93.9	639	+15	94.5	605	+4	94.4	611	0
31	94.8	551	−1	94.8	546	−6	94.4	552	−1	94.4	535	−4	95.3	541	−7	93.9	637	+4
32	94.0	571	+2	95.0	612	+6	94.4	572	+2	94.4	443	−20	95.2	520	−10	94.9	720	+18
33	95.3	--------	--------	95.6	522	−10	95.2	521	−7	94.1	440	−21	94.9	545	−6	94.3	549	−10
34	94.2	500	−10	94.6	571	−2	94.5	555	−1	94.2	553	−1	94.3	521	−10	94.6	563	−8
Average	94.6	558	9	94.5	580	7	94.4	560	8	94.4	556	7	94.3	579	6	94.2	611	7

[1] Not included in average.

smoothed off with a steel float. These tools are shown on top of the steel beam mold in Figure 1.

All of the concrete was a 1:2:3½ mix, proportioned by dry rodded volumes and was of a stiff consistency, averaging a flow of 125 on a 30-inch flow table.

Half of the specimens were made of concrete in which a very angular crushed stone was used as the coarse aggregate and the other half were made of concrete in which a well-rounded gravel was used. The coarse aggregate was proportioned from three separate sizes in both cases and the maximum size was 1¼ inches. The fine aggregate was in all cases a very clean, high grade, concrete sand.

A water-cement ratio of 0.84 was used for the concrete containing the crushed-stone aggregate and 0.80 for that containing the gravel aggregate. The specimens were 6 by 6 by 30 inches and were left in the molds under wet burlap for 24 hours, after which they were placed in a damp room for 27 days. Weather effects were eliminated so far as possible by fabricating two specimens by each of the six methods each day. Thus the specimens made by the different methods are affected by exactly the same weather conditions.

Tests in flexure were made at 28 days in a universal testing machine operated by a hand wheel using the set-up shown in Figure 2. It will be noted that the middle third of the span was subject to a constant bending moment. One break was obtained for each specimen, the top surface as molded being in tension during the test.

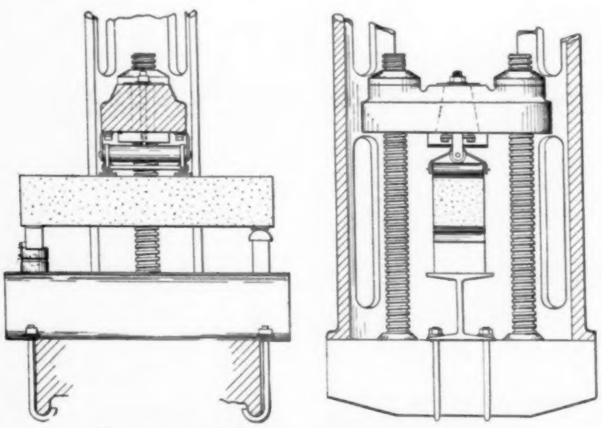


FIGURE 2.—METHOD OF TESTING BEAMS

STRENGTH DATA FROM SPECIMENS MADE BY VARIOUS METHODS

Tables 1 and 2 give all of the data, Table 1 containing the data for the beams of gravel concrete and Table 2 containing corresponding data for those of crushed-stone concrete. The weight of each specimen and its modulus of rupture are given. The average modulus of rupture was computed for all of the specimens made by each method and the percentage of variation of each modulus of rupture value from this average was computed and entered in the table. These variations are averaged at the foot of the column.

These data are summarized for the six methods of fabrication as follows:

Rounded aggregate

	Method					
	1	2	3	4	5	6
Average modulus of rupture, pounds per square inch	535	537	528	544	548	562
Average variation from the average, per cent	8	10	7	6	7	7
Average weight of specimen, pounds	92.7	92.8	92.8	92.5	92.4	92.6

Angular aggregate

	Method					
	1	2	3	4	5	6
Average modulus of rupture, pounds per square inch	558	580	560	556	579	611
Average variation from the average, per cent	9	8	8	7	6	7
Average weight of specimen, pounds	94.6	94.5	94.4	94.4	94.3	94.2

Before passing to a discussion of the data presented there were certain observations made regarding the use of the various methods which are of considerable importance in making comparisons. Comparing methods 1 and 2, the additional rodding specified for the latter method added but little to the total labor required to make the specimen. The operator had the impression that better compaction was obtained with the additional rodding.

The spading required in methods 3 and 4 seemed to stiffen up the concrete and gave it a well-mixed appearance. It was more difficult to force the spade down along the mold in the case of these two methods than with any of the others and there appeared to be more resistance to screeding the surface, particularly with method 4.

Method 5 showed a tendency to stiffen the concrete although this was not nearly so marked as in the case of methods 3 and 4. The small tamper used in this method did not operate to produce a plane through the specimen where the two layers of concrete came together.

With method 6 there was a decided tendency to form a plane between the two layers of concrete. The large tamper did not distribute the concrete well but a marked tamping action was apparent. It seemed that there was more effect from variations in the force of the blow struck in this than in any of the other methods employed. The large tamper was difficult to manipulate skillfully.

DATA INDICATE LITTLE DIFFERENCE BETWEEN RODDING AND SPADING METHODS

From the standpoint of the strength of the specimens obtained with the various methods the data indicate that there is little difference between the first five methods. The large tamper used in method 6, however, seems to give somewhat greater strength and this is particularly noticeable in the case of concrete containing the angular aggregate.

An examination of the data for uniformity based on the variations of the individual specimens from the

(Continued on p. 115)

EFFECT OF MOISTURE CONTENT ON THE STRENGTH OF CEMENT MORTAR SPECIMENS

By D. O. WOOLF, Assistant Materials Engineer, and BAXTER SMITH, Assistant Scientific Aide

IT HAS been known for some time that air-dry cement-mortar specimens give higher strength values in compression than do specimens which are thoroughly saturated with water. There are a number of tests to demonstrate this, but it is doubtful if, in many cases, the specimens have had identical curing. In the majority of instances, the specimens which were tested dry appear to have been cured in water for a short period and then air-cured until test. This method gives results which are affected not only by the condition of the specimen at test but also by the method of curing.

In an investigation to determine the effect of the condition of the specimen at the time of test on the strength and which was not influenced by the curing method, a number of sets of tension briquets, 2-inch cubes, and 2 by 3 by 12 inch beams were made of 1 : 2 sand-mortar. These specimens were cured in water for six months. The specimens to be tested wet were kept in water until placed in the testing machine; the other specimens were dried in warm air for two days prior to test. In the case of the beams, it was desired to make one wet and one dry test on the same specimen; consequently, after test in a wet condition, the larger portion of the broken beam was dried in warm air for two days and then tested. The 2-day difference in age between the wet and dry specimens may be ignored in consideration of the age of the specimens at test.

The beams were tested in a cantilever beam testing machine, which is described in the May, 1928, issue of PUBLIC ROADS. Tension and compression tests were made in standard machines of 1,000 and 40,000 pounds capacity, respectively. The test results are given in the accompanying tables.

It will be noted that the wet specimens gave higher strengths in tension and flexure and the dry specimens gave higher strengths in compression. According to one theory, which has been presented[1] the cement paste which incorporates the aggregate particles shrinks upon drying and develops a tensile stress between the individual particles comprising the cement paste. When the specimen is resaturated with water, the material expands and it would then appear that the initial tensile stress in the cement paste is reduced to zero. The reason for the difference in strength between the wet and dry specimens may then be explained by the presence of this internal stress in the dried cement paste. When a dried concrete specimen is tested in compression, this initial tension must be overcome before the specimen is actually put in compression, thereby increasing the observed load, whereas when a dried specimen is tested in tension, the initial tension will operate to reduce the total observed load.

Less variation from the average is found in the wet specimens than in those which were tested in a dry condition, the mean variations being 3.6 per cent for the wet specimens and 5 per cent for the dry ones.

[1] Article entitled "Facts from the Laboratory," Concrete Highway and Public Improvements Magazine, October, 1928.

Effect of moisture on strength of 1:2 mortar at age of 6 months

STRENGTH IN TENSION—POUNDS PER SQUARE INCH

Set No.	Wet				Dry				Change in strength[1]
	1	2	3	Av.	1	2	3	Av.	
									Per cent
1	565	510	510	530	395	330	380	370	30
2	550	500	510	520	385	405	310	365	30
3	550	550	510	535	460	355	320	380	29
4	565	565	535	555	335	395	395	375	32
5	515	520	585	540	430	400	330	385	29
6	495	495	535	510	450	480	330	410	19
Average				530				380	28

STRENGTH IN COMPRESSION—POUNDS PER SQUARE INCH

1	6,650		6,650	6,650	6,640	8,385	7,220	7,415	12
2	6,690	6,745	6,280	6,570	7,045		7,200	7,120	8
3	4,630		5,425	5,025	7,590	5,940	6,215	6,580	31
4	6,350	6,545	6,240	6,380	6,690		6,730	6,710	5
5	6,125		6,600	6,360	8,510	8,370	6,930	7,930	25
6	6,355	6,480	6,105	6,315	7,305		6,955	7,130	13
Average				6,215				7,145	15

[1] Based on strength of wet specimens.

MODULUS OF RUPTURE—POUNDS PER SQUARE INCH

Set No.	Wet		Dry		Change in strength[1]
	Load	Modulus of rupture	Load	Modulus of rupture	
	Pound	*Lbs. per sq. in.*	*Pound*	*Lbs. per sq. in.*	*Per cent*
1	105.5	650	69.0	430	34
2	106.0	650	63.0	390	40
3	114.0	700	77.5	480	31
4	116.5	715	73.6	455	36
5	109.3	670	79.0	490	27
6	109.0	670	68.0	425	37
Average		675		445	34

[1] Based on strength of wet specimens.

SIMPLE LABORATORY EXPERIMENTS ON CAPILLARY MOVEMENT AND ENTRAPPED AIR IN CLAYS

By DMITRY P. KRYNINE, Professor of Highway Engineering, Moscow Superior Technical School and Moscow Institute of Transportation Engineering

THE HIGHWAY engineer is generally perfectly familiar with the meaning of the term "capillary movement" of water in soils. During and after rains, when the surface soil is more moist than the lower layer, the capillary movement added to the action of gravity causes the water to penetrate into the ground; when the surface soil has been dried by sun and wind, the capillary flow is upward. It may be said that in dry clay, capillary movement may take place upward, downward, or laterally. The usual terms "capillary rise" or "capillary upward movement" convey an inexact idea and should be used only to express a restricted meaning.

DIRECTION OF CAPILLARY MOVEMENT DEMONSTRATED

The direction of capillary movement may be demonstrated by a simple experiment using the apparatus shown in Figure 1. The box (1) is filled with dry clay powder. The white line (3) corresponds to the top of a glass tube in the interior of the box; the water is conducted to this tube from a glass funnel; (2) is simply a rubber tube. The permanent level of water at the elevation of the white line (3) is maintained by dropping water from the dropper (4). After a certain time the front side of the box is taken away, and in the middle of the dry soil a round body is to be found. It may be easily cleaned of dry clay particles; its view is represented in Figures 2 and 3. It is not a perfect sphere, but an ellipsoid, called by the writer "ellipsoid of setting." The vertical axis of this ellipsoid is generally shorter than the horizontal one, and the difference depends upon the mechanical composition of the clay as well as upon it density.

The phenomenon may be also demonstrated with a metallic rectangular box with a single hole about one-fourth inch in diameter in the center of the bottom. Fill the box with dry clay powder and put it into water, the level of which must be maintained just even with the bottom. After a certain time (for instance, half an hour) a semiellipsoid of wet clay may be found in the box.

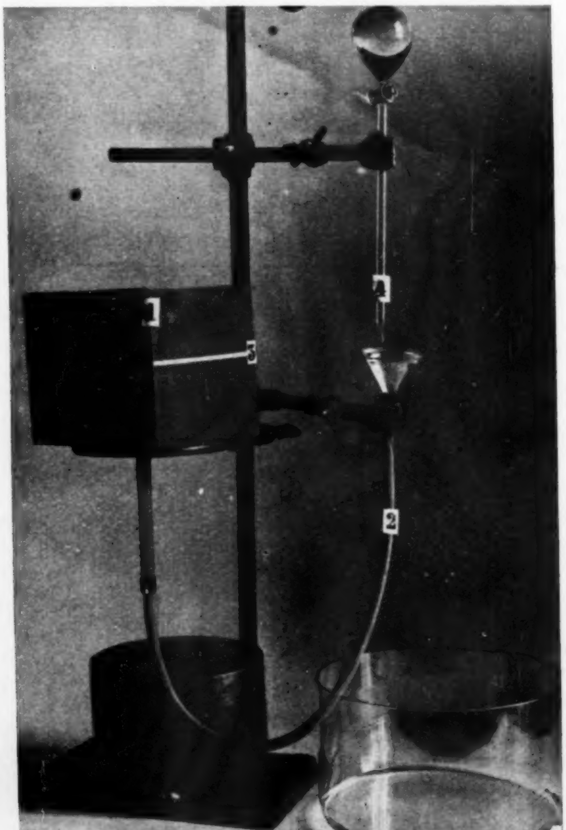


FIGURE 1.—APPARATUS FOR DEMONSTRATING CAPILLARY MOVEMENT OF WATER IN CLAY

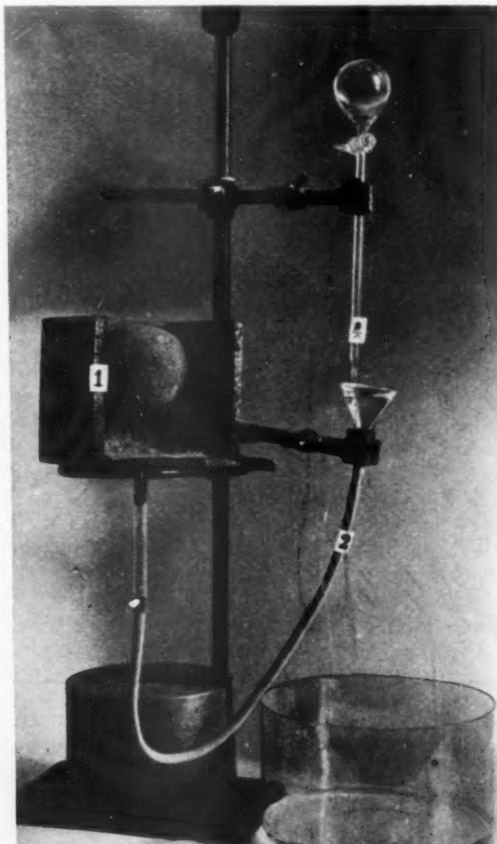


FIGURE 2.—ELLIPSOID OF MOIST CLAY FORMED BY CAPILLARY MOVEMENT OF WATER

Naturally, the dry clay must be accurately deposited in thin layers and preferably through a rubber tube.[1]

Capillary movement is due to molecular attraction of water by clay particles. A part of the attracted water sticks to the surfaces of the particles, and another part moves forward to a certain point when the movement stops apparently. Thus in clay ground there are clay particles and capillary water. In addition, air is also present in the clay, especially in its upper cushions. The writer thinks the air present in soil may act in three different ways: (*a*) So that in one way or another it communicates to the surrounding atmosphere and assumes directly the temperature and the pressure of the nearest particles of the atmosphere; (*b*) so that it does not communicate to the atmosphere by means of air channels, but stands under a pressure, which is determined by the state of stress which exists in the water; this is analogous to a bubble in a spirit level, and may be termed "entrapped" or "pinched" air, often microscopic in size, and (*c*) as absorbed air which sticks like glue to the particles of soil.

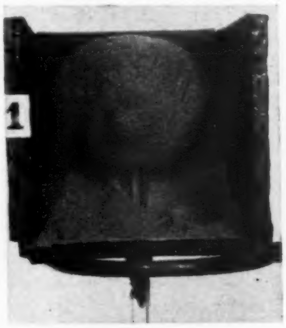


FIGURE 3.—ELLIPSOID OF MOIST CLAY

During the capillary movement the water replaces the air in the soil pores and drives it forward. Let us see this phenomenon in a simple experiment using the apparatus shown in Figure 4.

The glass tube (1) has the bottom end covered with cheesecloth and is accurately filled with dry clay. Pour some water on the top of the soil column and the penetration of water into soil begins immediately. Some minutes after, put the bottom end into water. One or two minutes after a crack will be noted just on the limit between the wet soil and the dry soil. The crack augments and raises the soil cork (3); indicating that the air driven from the bottom of the tube by the capillary water is accumulated in the spot (4). The cork (3) is impermeable to the water penetrating into the soil from top to bottom and to the air moving from bottom to top.

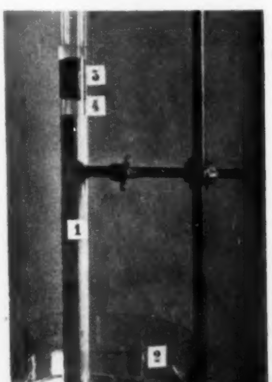


FIGURE 4.—APPARATUS USED IN DEMONSTRATING ACTION OF CAPILLARY WATER IN DRIVING AIR FROM PORES OF SOIL

Naturally, the air accumulated in the spot (4) is not entrapped air in its strict meaning, but in any case it is an accumulation of entrapped air.

Take the tube out of the basin and the air at point 4 will find its way through the bottom of the tube and the cork (3) begins to lower. As soon as its lower surface touches the dry soil, the penetration of the water into soil will continue.

These simple facts were observed in the highway laboratory of the Moscow Superior Technical School by Prof. D. P. Krynine, N. V. Laletine, and A. A. Ehrlich, the former graduate and the latter undergraduate in civil engineering, coworkers.

[1] For a description of method of depositing see "Elementary Proof of Shale-likeness of Clay Particles," by D. P. Krynine, Public Roads, vol. 8, no. 11, January, 1928.

(Continued from p. 112)

averages for the various series shows that about the same average variation and about the same dispersion obtains for all of the six methods. The only exception is in the data for method 2 in Table 1 (rounded aggregate.) Here, for no obvious reason, there are an unusual number of variations of the order of 15 per cent. In general, it may be said that the uniformity of the strength data does not seem to be affected to any important degree by the methods of fabrication used in these tests.

It was hoped that the weights of the specimens would reflect the degree of compaction obtained by the various methods since all of the specimens were made in accurately machined steel molds which have the same volumes within close limits. The weights are a measure of the average density of the specimens but some of the methods used did not give specimens of uniform density. This was particularly noticeable in the case of the large tamper (method 6) where the angular aggregate was used. The specimens were not thoroughly compacted in the corners and this seems to be the explanation for the fact that this group showed the lowest average weight. These same specimens showed the highest average strength of any in which this concrete was used and this was probably due to the compaction obtained in the critical section by the use of the large tamper.

From observations made during these tests the rodding and spading methods are more apt to give specimens which appear to have uniform density than are the tamping methods. Considered from the standpoint of practical operation there are arguments for both the spading and the rodding methods. It is necessary to spade the specimen along the sides and ends and if the same tool would suffice for compacting the specimen then only one tool need be taken on the job. On the other hand the rodding of specimens is well established and the rods used are easy to procure. There are also advantages in the use of the same tools for the fabricating of both compression and flexure specimens. As far as ease of manipulation is concerned, it is not believed that there is any choice between the rod and the spade.

Tamping methods are not believed to be as satisfactory as rodding or spading because, in addition to the possibility of less uniform specimens, the force applied by the operator will have more effect than will be the case with a sharp-edged or pointed tool.

CONCLUSIONS

The following conclusions seem justified by the data obtained in this investigation:

That both the rodding and spading methods used are equally satisfactory so far as strength, uniformity and ease of fabrication are concerned.

That the additional manipulation of methods 2 and 4 over that of methods 1 and 3 results in little or no improvement in the specimens obtained.

That the tamping methods are not as satisfactory as are the rodding or spading methods.

RELATION OF COARSE AGGREGATE CONTENT TO THE QUALITY OF PAVEMENT CONCRETE TO BE STUDIED

An investigation to determine the effect of variations in the amount of coarse aggregate on the quality of Portland cement concrete in pavements constructed with standard equipment has been initiated by the Bureau of Public Roads and a series of nearly 250 slabs is now under construction at the Arlington Experiment Station near Washington. Experience in pavement construction in North Carolina has indicated that, with a close control of grading of the coarse aggregate, it may be possible to use a considerably larger quantity of coarse aggregate than has heretofore been customary and thereby effect appreciable economies in construction costs. It is desirable to investigate the matter by using standard construction equipment for making and finishing full-size test slabs laid under closely controlled conditions.

A single commercial concrete sand of good quality is being used as the fine aggregate in all of the slabs. The following variables have been included in the tests.

(*a*) Coarse aggregate of three types:

1. Crushed stone.
2. Rounded, uncrushed gravel.
3. Blast furnace slag. To be used with coarse aggregate grading No. 1 only.

(*b*) Coarse aggregate of two gradings:

1. Material graded from one-fourth inch to 2½ inches and containing a proper amount of one-fourth to three-fourths inch material.
2. In the second grading the crushed stone will be deficient in one-fourth to three-fourths inch material, but the gravel will carry an excess of this size and will be limited to a maximum size of 1½ inches.

The coarse aggregates will be measured in three commercial sizes, as follows: 2½ inches to 1¼ inches, 1¼ inches to three-fourths inch, and three-fourths to one-fourth inch.

(*c*) Six proportions (dry, rodded volumes) as follows:

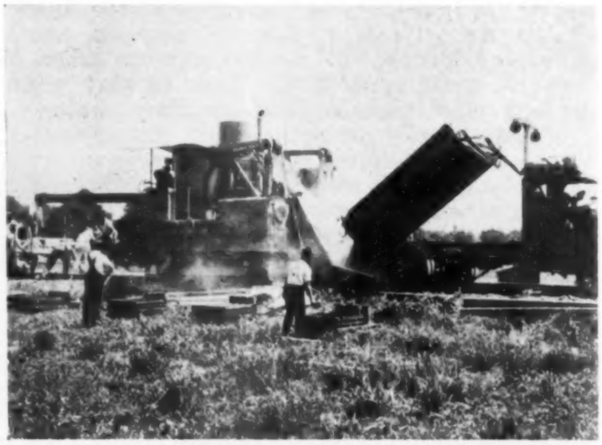
1. 1:2:3½.
2. 1:2:4.
3. 1:2:4½.
4. 1:2:4¾.
5. 1:2:5.
6. 1:2:5¼.

The addition of coarse aggregate will proceed only to the limit of workability for each aggregate. It is not expected that it will be feasible to use as much crushed stone or slag as gravel.

(*d*) Three consistencies are being used ranging from the driest which can be placed and finished to a relatively wet mix which can be handled easily.

(*e*) Two finishing machines are being used.

The pavement slabs are 9 feet square and 7 inches thick and are placed with the use of steel side forms.



PLACING CONCRETE SLABS AND CASTING SPECIMENS

Mixing, placing and finishing of the concrete is in accordance with modern paving practice using standard equipment.

The slabs are divided longitudinally by dummy joints or planes of weakness and the various sections are separated by transverse headers. The mixing time is one minute. The slabs are covered with wet burlap for 24 hours, followed by wet earth for 10 days. Detailed observations are being made as to consistency, workability and yield.

After curing the slabs are to be drilled for cores and subdivided into beams suitable for flexure tests. The strength tests will be made at an age which will be determined later.

Supplementary tests are also to be made on beams and cylinders cast at the time the pavement slab is placed. These tests should yield data as to the relationship between the strength of molded specimens and that of specimens cut from pavement slabs.

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Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.
Report of the Chief of the Bureau of Public Roads, 1927.
Report of the Chief of the Bureau of Public Roads, 1928.

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388D. Public Road Mileage and Revenues in the New England States, 1914.
390D. Public Road Mileage and Revenues in the United States, 1914. A Summary.
407D. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
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*532D. The Expansion and Contraction of Concrete and Concrete Roads. 10c.
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Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio.
Report of a Survey of Transportation on the State Highways of Pennsylvania.

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Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 24, D- 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced-Concrete Slabs Under Concentrated Loading.
Vo. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

* Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CURRENT STATUS OF FEDERAL AID ROAD CONSTRUCTION

AS OF

JULY 31,1929

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS	STATE
		Estimated total cost	Federal aid allotted	MILEAGE			Estimated total cost	Federal aid allotted	MILEAGE				
				Initial	Stage[1]	Total			Initial	Stage[1]	Total		
Alabama	2,001.4	$ 3,303,433.11	$ 1,649,690.13	169.6	35.3	204.9	$ 162,471.28	$ 81,235.64	6.4		6.4	$ 2,092,087.81	Alabama
Arizona	881.4	2,333,123.14	1,959,930.61	100.6	36.5	137.1	365,945.99	275,520.72		49.6	49.6	2,449,552.91	Arizona
Arkansas	1,760.3	3,448,479.21	1,708,853.23	104.4	.3	104.7	989,180.77	461,359.70	43.8	18.6	62.4	1,779,183.86	Arkansas
California	1,661.7	8,579,036.36	3,814,653.56	226.6	16.6	243.2	2,694,409.36	1,372,172.10	71.6	3.6	75.2	239,953.70	California
Colorado	1,140.8	3,600,156.93	1,936,877.39	125.4	26.7	152.1	836,179.08	456,709.20	28.9	12.4	41.3	1,652,294.97	Colorado
Connecticut	229.3	792,275.72	217,937.99	12.5		12.5	1,448,304.86	597,151.39	8.1		8.1	541,678.71	Connecticut
Delaware	212.9	1,000,750.60	422,535.31	26.5		26.5	348,886.30	189,111.65	26.4		26.4	16,793.31	Delaware
Florida	449.0	2,734,529.08	1,135,234.01	90.9	5.7	96.6	1,198,416.45	546,245.10	18.5		18.5	1,419,681.52	Florida
Georgia	2,560.3	3,714,872.98	1,651,786.05	160.0	36.9	196.9	80,045.51	39,651.03	6.8		6.8	2,020,202.65	Georgia
Idaho	1,154.6	960,347.49	575,451.57	71.1		71.1	128,110.17	77,013.98	12.7		12.7	628,996.57	Idaho
Illinois	1,896.9	19,279,530.52	8,608,307.86	566.8		566.8	648,000.00	324,000.00	22.5		22.5	2,606,225.00	Illinois
Indiana	1,285.5	9,251,722.07	4,361,519.02	282.7		282.7	318,800.00	146,900.00	9.1		9.1	166,416.93	Indiana
Iowa	2,989.9	4,423,313.15	1,994,509.17	63.3	96.5	159.8	1,480,505.60	542,805.35	10.8	42.8	53.6	21,069.26	Iowa
Kansas	2,605.0	3,317,585.94	1,369,304.60	198.7		198.7	2,540,863.30	1,207,494.09	154.8	21.3	176.1	652,884.20	Kansas
Kentucky	1,312.9	5,083,872.90	2,437,259.89	268.4	5.1	273.5	159,709.06	79,854.52	18.6		18.6	680,227.30	Kentucky
Louisiana	1,321.4	3,623,495.55	1,803,989.15	151.9		151.9	222,531.67	84,736.17	12.2		12.2	1,171,119.61	Louisiana
Maine	484.0	1,685,160.83	602,306.36	40.9		40.9	1,226,693.86	480,634.53	35.9		35.9	1,032,825.22	Maine
Maryland	615.3	576,613.50	266,360.00	23.3	12.6	35.9	940,222.22	409,160.00	34.1	4.2	38.3	57,275.37	Maryland
Massachusetts	576.8	4,929,914.57	1,435,067.84	83.5	3.4	86.9						1,795,624.15	Massachusetts
Michigan	1,486.2	10,825,067.05	4,604,539.75	258.6	9.4	268.0	1,397,000.00	571,278.33	32.3	3.9	36.2	1,148,871.96	Michigan
Minnesota	3,872.6	5,772,191.38	1,956,916.23	270.9	93.4	364.3	1,177,929.23	191,000.00	55.6	16.6	72.2	350,000.00	Minnesota
Mississippi	1,671.6	4,946,114.79	2,183,951.33	194.8	17.4	212.2	86,167.73	43,083.86	.1		.1	1,296,617.09	Mississippi
Missouri	2,243.1	10,780,721.28	4,136,457.42	212.0	109.0	321.0	1,241,078.76	472,605.63	3.4	37.9	41.3	149,733.36	Missouri
Montana	1,550.7	5,877,518.24	3,637,856.52	415.4	7.6	423.0	2,163,786.22	1,139,460.77	185.8	11.5	197.3	2,881,816.94	Montana
Nebraska	3,577.3	4,032,493.03	1,959,500.93	270.2	117.5	387.7	2,546,507.30	1,198,706.62	110.3	98.8	209.1	1,521,823.63	Nebraska
Nevada	1,097.5	1,046,025.45	917,509.27	94.2	116.8	211.0	383,646.13	340,869.50	32.9	56.4	89.[illegible]	45,203.86	Nevada
New Hampshire	336.1	699,115.45	245,188.29	15.5	1.0	16.5	181,527.71	40,620.00	2.7		2.7	147,546.98	New Hampshire
New Jersey	465.2	4,680,197.58	807,030.00	53.8		53.8	630,305.20	198,450.00	13.2		13.2	525,765.08	New Jersey
New Mexico	1,880.3	2,119,426.90	1,339,546.08	125.3		125.3	894,699.44	570,370.85	38.3		38.3	737,178.75	New Mexico
New York	2,240.6	24,862,617.76	5,306,000.55	354.6		354.6	7,662,300.00	1,631,555.00	109.3		109.3	3,698,852.90	New York
North Carolina	1,723.4	1,329,286.15	664,643.05	82.3	7.2	89.5	475,537.08	233,684.54	25.3	10.2	35.5	1,534,718.37	North Carolina
North Dakota	3,745.1	2,895,755.08	1,158,854.77	437.2	145.3	582.5	1,166,158.84	457,977.78	144.0	204.8	348.8	784,332.58	North Dakota
Ohio	2,060.2	11,060,088.56	3,870,661.10	218.4	9.4	227.8	5,571,004.29	1,369,854.50	82.4	9.9	92.3	2,162,148.96	Ohio
Oklahoma	1,826.6	2,040,304.93	920,520.97	96.1	5.8	101.9	836,881.22	358,914.13	18.2	17.1	35.3	923,985.53	Oklahoma
Oregon	1,137.5	1,632,197.37	850,178.01	104.0	22.1	126.1	934,429.96	581,496.71	40.4	29.3	69.7	979,707.98	Oregon
Pennsylvania	2,078.6	14,842,357.58	3,834,819.04	232.5	14.1	246.6	3,247,943.76	1,005,810.57	64.7		64.7	1,572,325.63	Pennsylvania
Rhode Island	169.4	1,268,497.02	341,621.55	19.8		19.8	70,170.40	22,755.00	1.5		1.5	556,598.48	Rhode Island
South Carolina	1,813.8	4,170,783.90	846,426.61	133.2	37.3	170.5	338,037.05	84,000.00	29.0		29.0	864,635.19	South Carolina
South Dakota	3,329.2	3,745,939.81	2,016,219.47	458.4	59.5	517.9	382,417.73	200,289.20	48.9	13.9	62.8	371,571.75	South Dakota
Tennessee	1,174.1	3,009,466.78	1,378,542.18	94.2		94.2	407,838.42	203,919.19	20.6		20.6	1,078,917.72	Tennessee
Texas	6,090.7	18,498,279.21	7,931,915.31	710.9	264.9	975.8	4,692,963.02	1,907,668.69	91.8	108.2	200.0	74,512.79	Texas
Utah	921.4	1,760,559.92	1,190,043.71	77.2		77.2	472,631.39	296,873.22	12.8		12.8	200,248.13	Utah
Vermont	234.5	1,869,618.21	540,049.66	32.6		32.6	19,879.76	9,939.88	.1		.1	62,872.48	Vermont
Virginia	1,345.5	2,904,639.80	1,245,445.71	100.3	18.9	119.2	1,070,402.72	377,487.15	38.3	3.1	41.4	499,535.16	Virginia
Washington	859.2	4,192,102.02	1,465,075.25	90.2	18.1	108.3	1,306,037.98	395,000.00	14.8	11.7	26.5	717,100.03	Washington
West Virginia	670.1	3,667,437.23	1,518,429.83	84.9	27.6	112.5	461,427.94	170,041.53	7.4	7.1	14.5	66,244.99	West Virginia
Wisconsin	2,080.3	9,274,688.05	4,192,470.01	304.9	27.7	332.6	549,379.53	274,626.98	22.7		22.7	129,117.91	Wisconsin
Wyoming	1,662.8	1,679,385.89	1,080,735.76	178.2	26.2	204.4	357,755.01	233,822.03	22.1	25.4	47.5	93,248.61	Wyoming
Hawaii	39.5	402,281.10	137,426.82	6.6		6.6	562,688.38	247,259.61	16.6		16.6	1,072,664.16	Hawaii
TOTALS	78,523.3	$ 248,071,331.25	$100,230,149.01	8,494.3	1,431.8	9,926.1	$ 57,056,708.66	$ 22,242,167.59	1,806.7	818.3	2,625.0	$ 47,470,984.05	TOTALS

[1]The term stage construction refers to additional work done on projects previously improved with Federal aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.

U. S. GOVERNMENT PRINTING OFFICE: 1929